

# *Status of E949 gamma analysis*

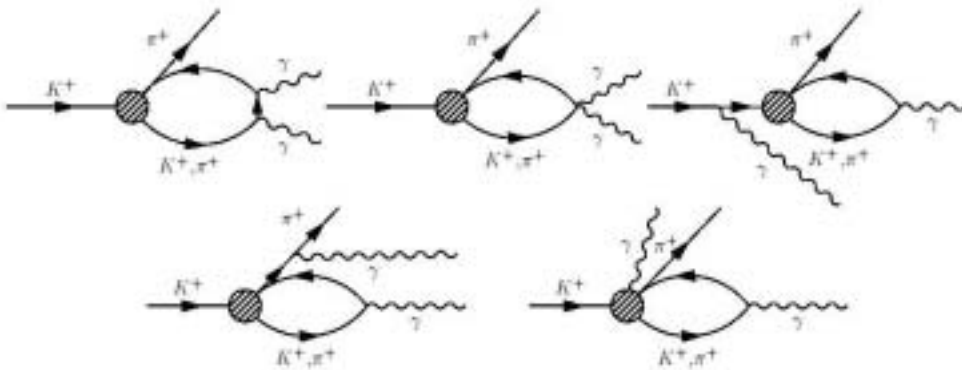
$$K^+ \rightarrow \pi^+ \gamma\gamma$$

Tamaki Yoshioka

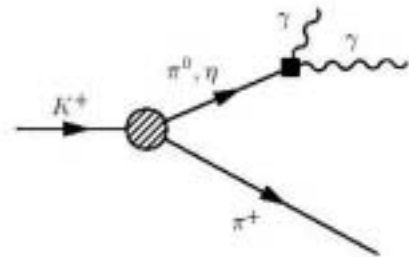
1. Physics Motivation
2. Analysis
  - Photon Reconstruction
  - Background Study
3. Summary and Future

# Physics Motivation(1)

- One of a stringent test of **Chiral Perturbation Theory**(ChPT).
  - There is no tree - level  $O(p^2)$  contribution and the leading contributions start at  $O(p^4)$ .



*loop diagrams*

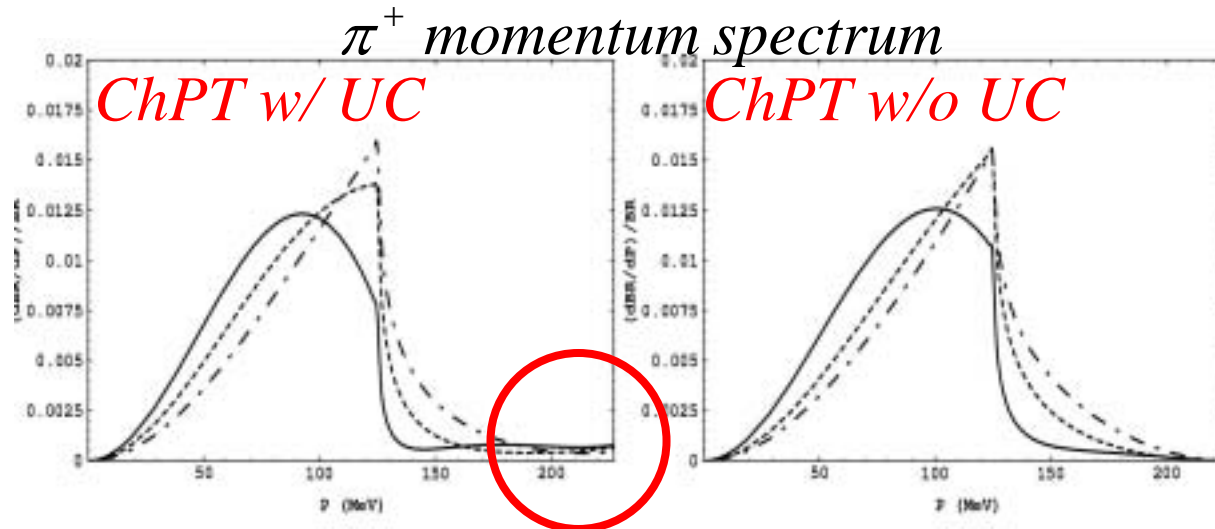


*anomalous diagram*

- The decay amplitude has one undetermined parameter  $\hat{c}$ . and is very sensitive to  $\hat{c}$ .

# Physics Motivation(2)

- Measurement of  $K_L \rightarrow \pi^0 \gamma \gamma$  indicate the necessity for higher order  $O(p^6)$  **U**nitaricity **C**orrection(UC).



*nonzero amplitude at the end point.*

- UC predicts nonzero amplitude at the end point and 30-40% higher branching ratio.

# *Physics Motivation(3)*

New  $\pi^+ \gamma \gamma$  trigger was installed to observe several signal events above the  $K_{\pi 2}$  region and to prove the existence of the UC.

- predicted branching ratio

	$Br(\pi^0 \gamma \gamma(1))$	$\hat{c}$
Phase Space	$1.70 \times 10^{-7}$	-
ChPT w/ UC	$5.66 \times 10^{-9}$	1.8
ChPT w/o UC	$3.41 \times 10^{-10}$	1.6

*If ChPT with UC is correct, several signal events will be observed from E949 data set.*

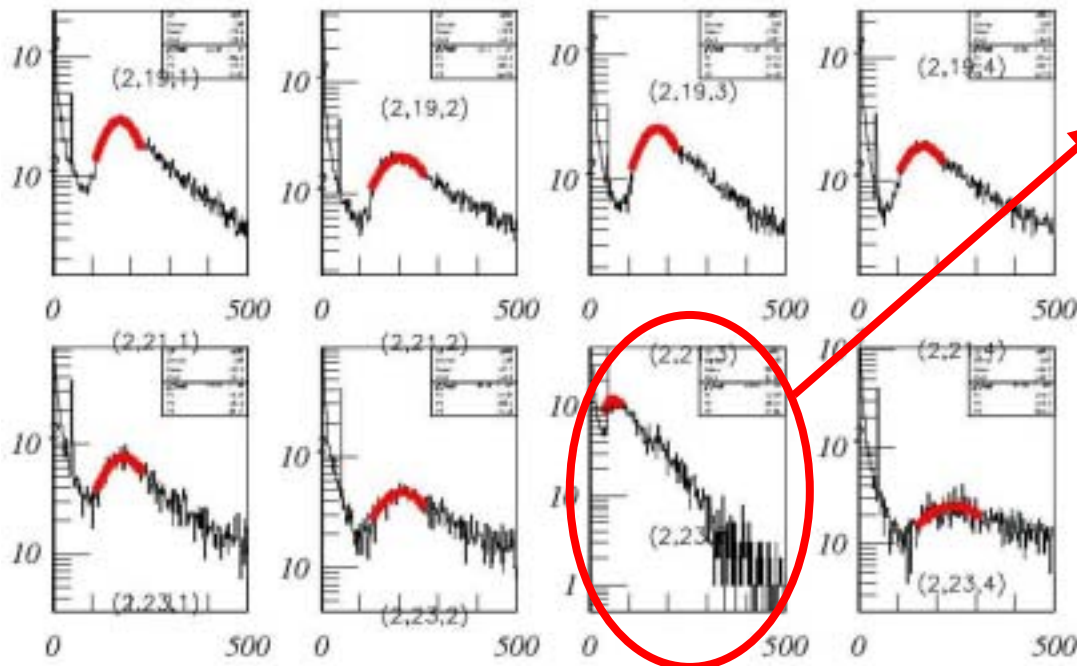
# *Analysis plan*

- develop new clustering code(BV+BVL). *done!*
- calibration
  - 1<sup>st</sup> calibration *done!*  
BV/BVLgain calibration, timing calibration
  - 2<sup>nd</sup> calibration *done!*  
visible fraction, parameters for z-position
- kinematic correction
- background study *just started...*

# *BV/BVL gain calibration*

- use geometric mean and logarithm of ratio of the both end.

$$\begin{cases} c_1 = \text{geomn} / E \times 10^{-\text{lograt}/2} \\ c_2 = \text{geomn} / E \times 10^{\text{lograt}/2} \end{cases} \quad \begin{array}{l} E : \text{most probable energy loss} \\ \text{for each layer} \\ c_1, c_2 \cong 16 \text{ counts/MeV} \end{array}$$

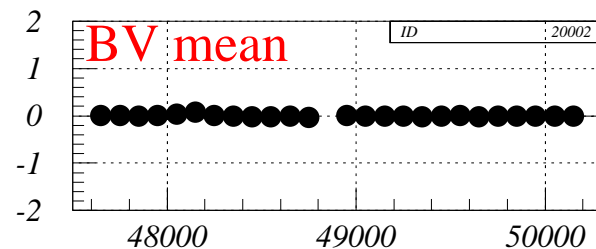


- **NOTE**  
BV lay3, sec23, DS  
seems to have bad gain.  
We may need to change  
the PMT at some point.

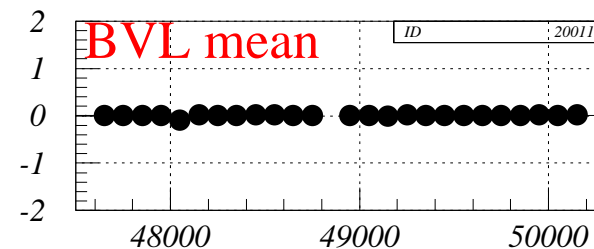
# *BV/BVL timing calibration*

- Data : kp22 monitors
- Procedure : find a shift in the BV/BVL timing(compared with the track time).

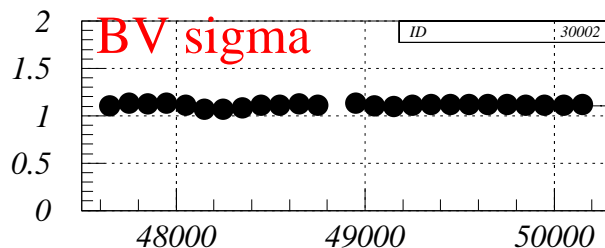
44 bv\_tof/bl\_tof files were produced and installed into CFM.



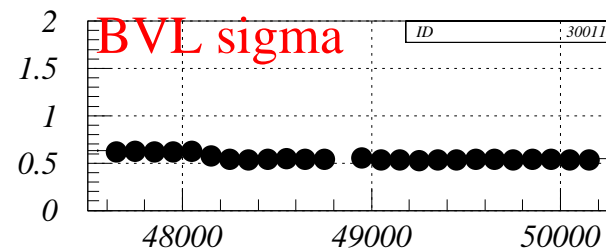
BV Timing(peak) vs run 02



BL Timing(peak) vs run 02



BV Timing(resol) vs run 02

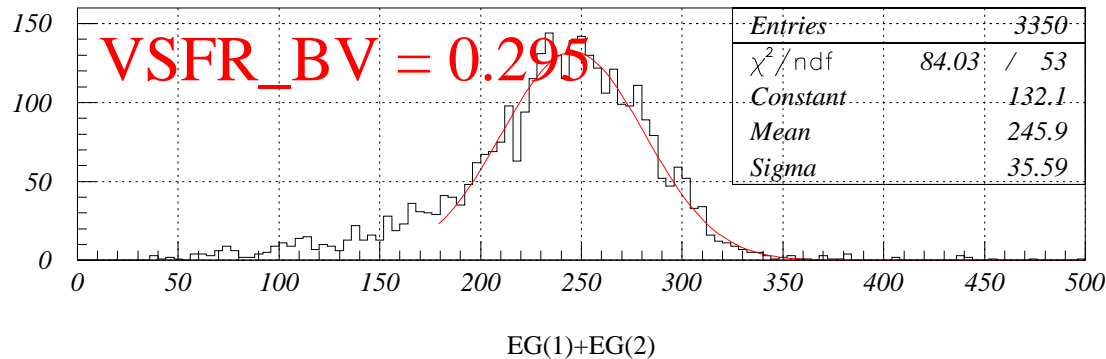


BL Timing(resol) vs run 02

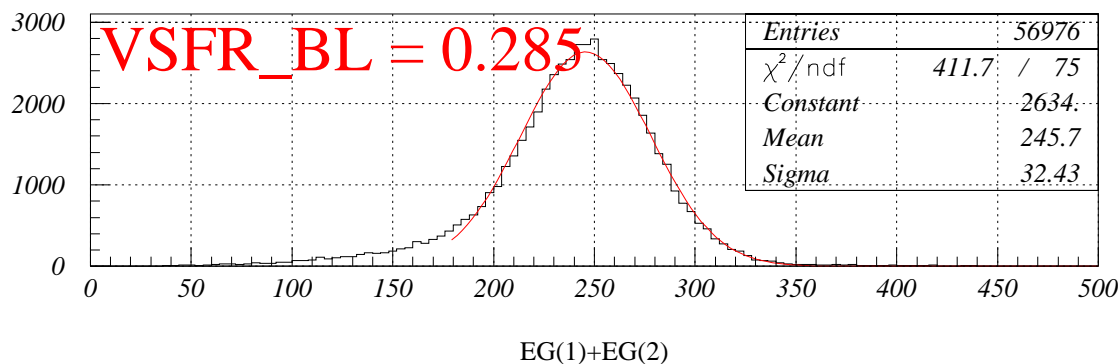
# *BV/BVL visible fraction(1)*

- *Method*

Sum up energy of the two highest-energy photons in BV/BVL and compare to expected energy from Kp2 decay.



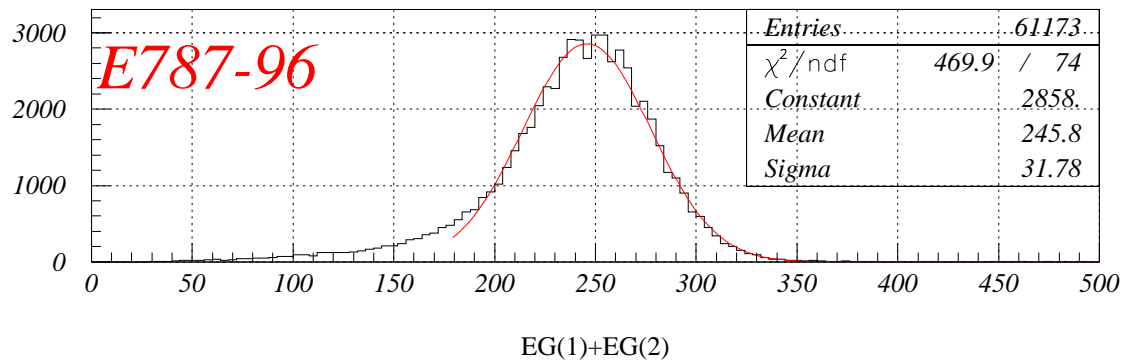
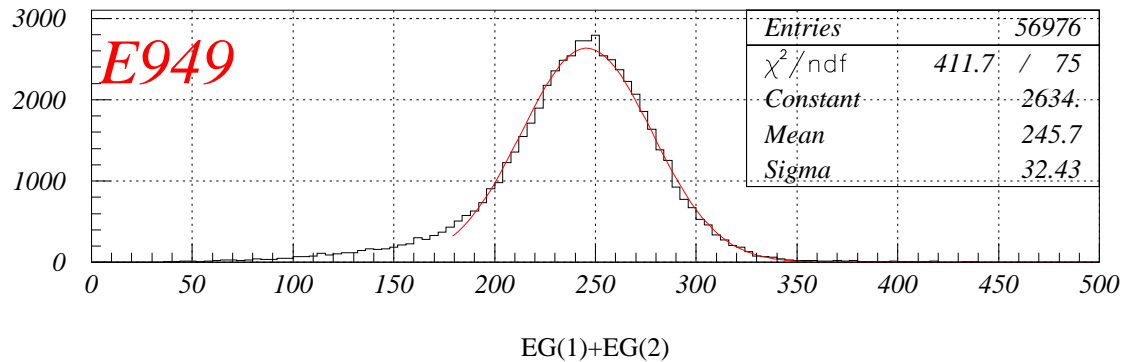
-First, visible fraction of BV was obtained by clustering BV only.  
(require no hit in BVL)



-Then, visible fraction of BVL was obtained by clustering BV+BVL.  
(consider BVL as 'BV layer-0')



# *BV/BVL visible fraction(2)*



	E787-96	E949
VSFR_BV	0.286	0.295
VSFR_BL	-----	0.285
sigma/mean	0.129	0.132

- The resolution is comparable to E787.

# *Parameters for BV z-position*

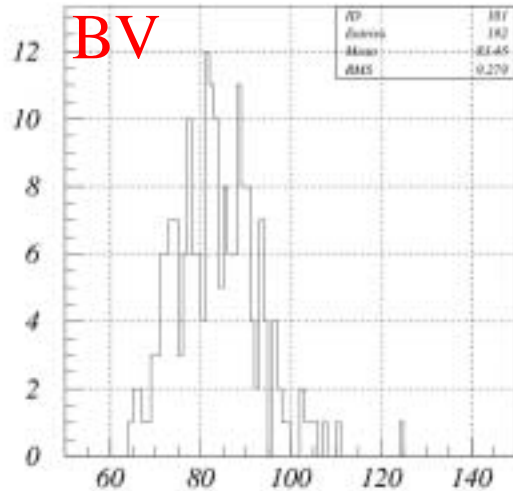
$$\begin{cases} z_{TDC} = \frac{v}{2}(t_2 - t_1) + O_{TDC} \\ z_{ADC} = \frac{\lambda}{2} \ln\left(\frac{a_2}{a_1}\right) + O_{ADC} \end{cases}$$

- assuming speed of light in BV/BVL 17.44cm/sec which is used in E787.

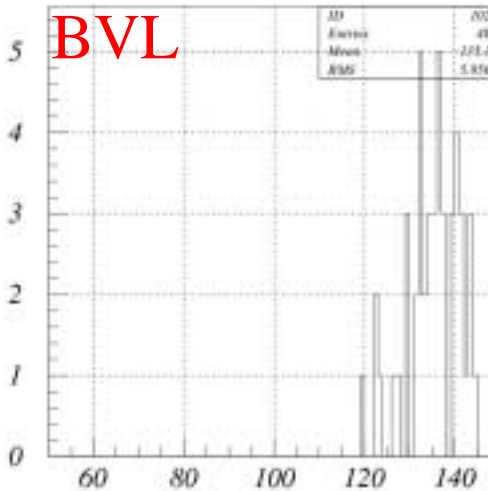
- combined z-position

$$z_{comb} = \frac{z_{TDC} + z_{ADC} \times \sqrt{E/10}}{1 + \sqrt{E/10}}$$

# *BV/BVL attenuation length*

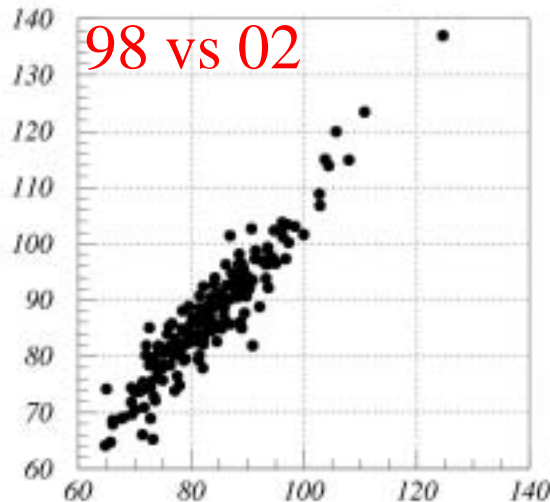


BV attenuation length

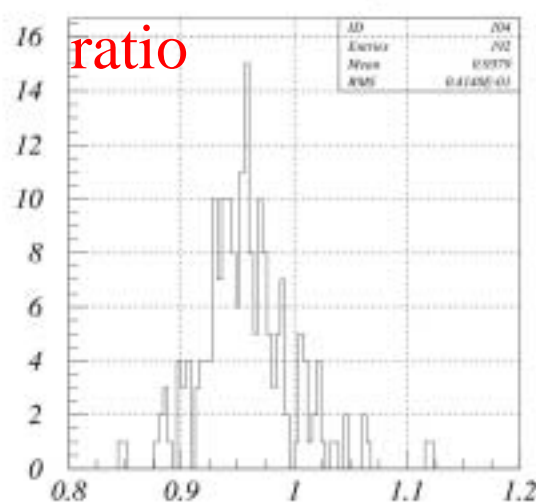


BL attenuation length

- mean value  
BV : ~83.45cm  
BVL : ~135.4cm



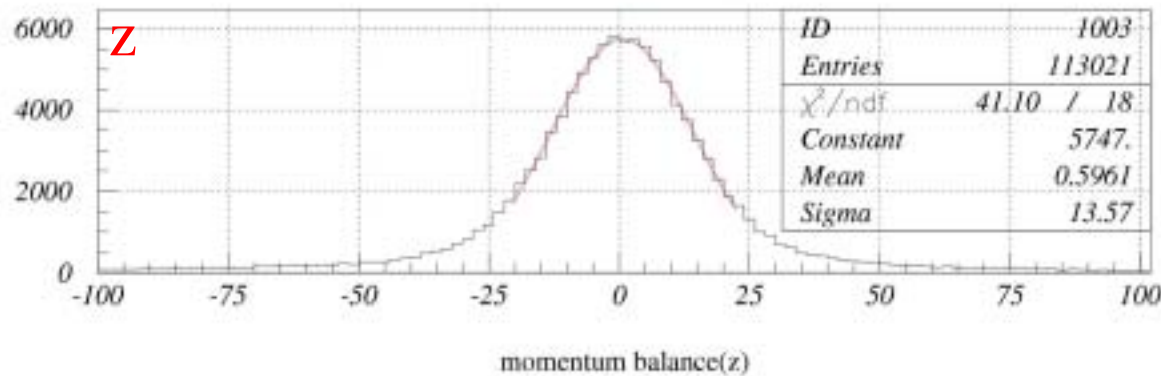
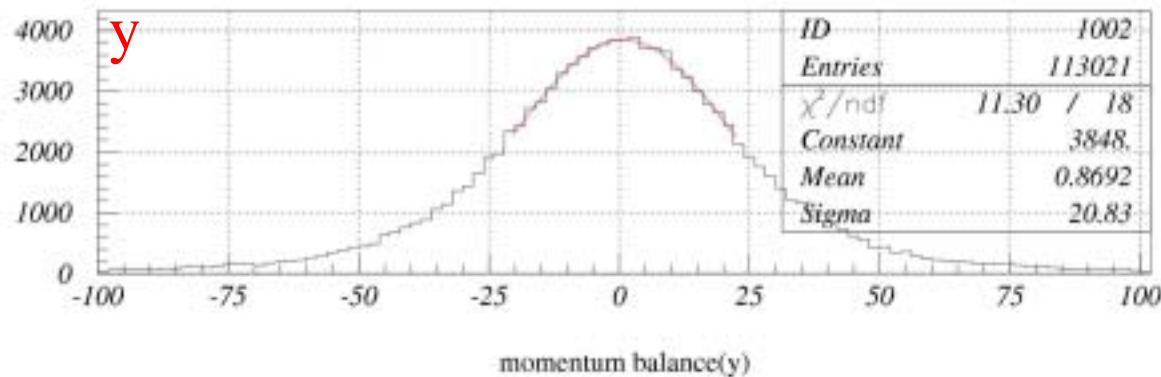
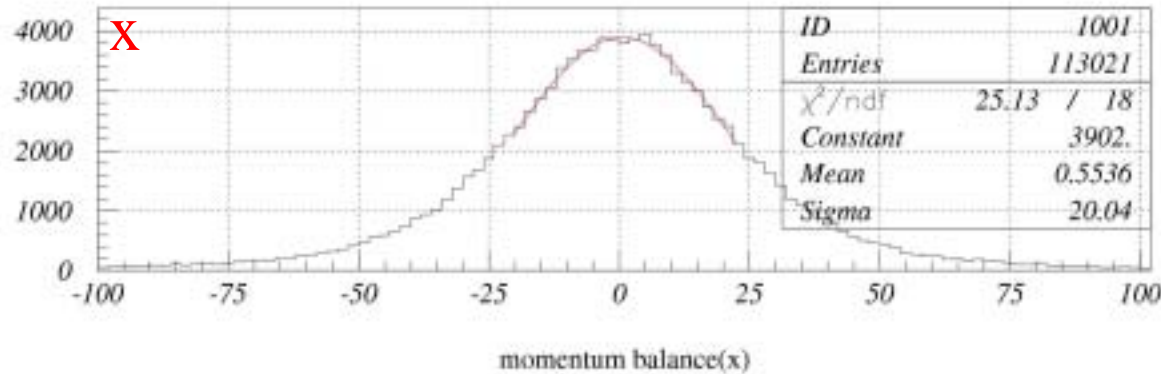
BV att 98 vs 02



BV att ratio

- The attenuation length for BV is decreased by ~4% since 98.

# Global z-offset

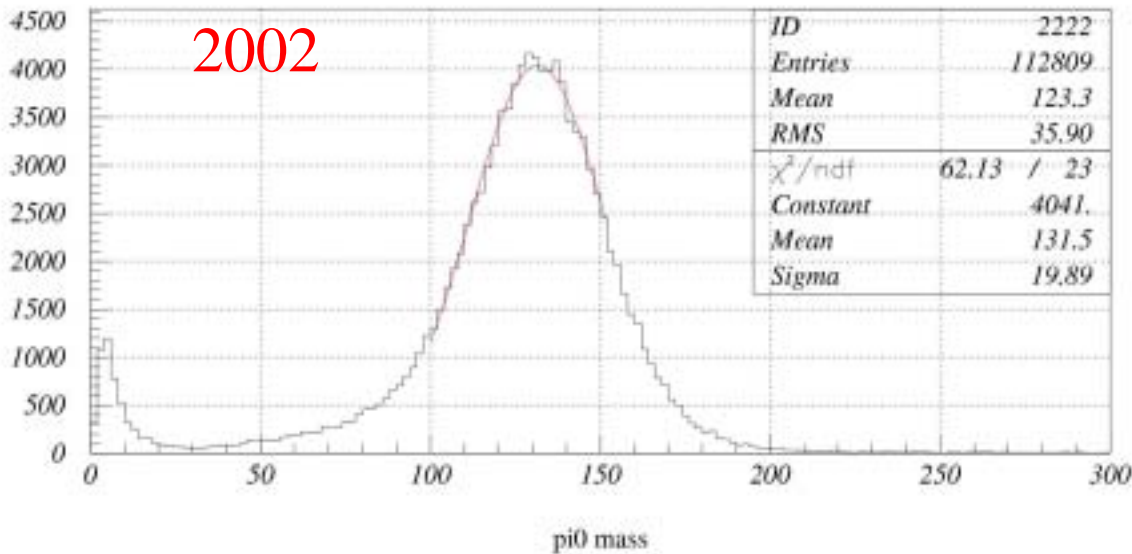


- require a momentum balance in z-direction is to be peaked at zero.

$$O_{TDC} = -4cm$$

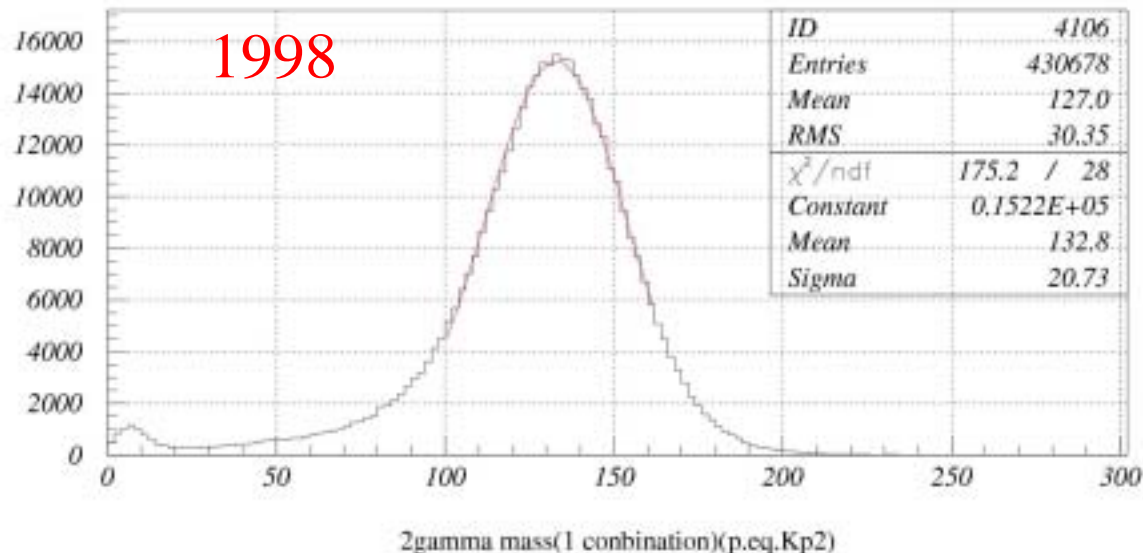
# After calibration...

2002



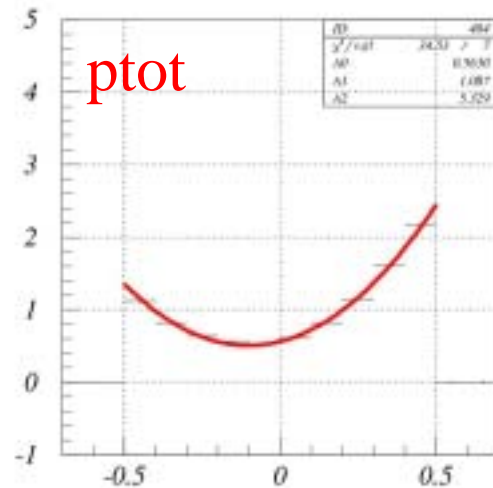
- The invariant mass of  $\pi^0$  from  $K^0 \rightarrow \pi^0 \pi^0$  decay was checked.

1998

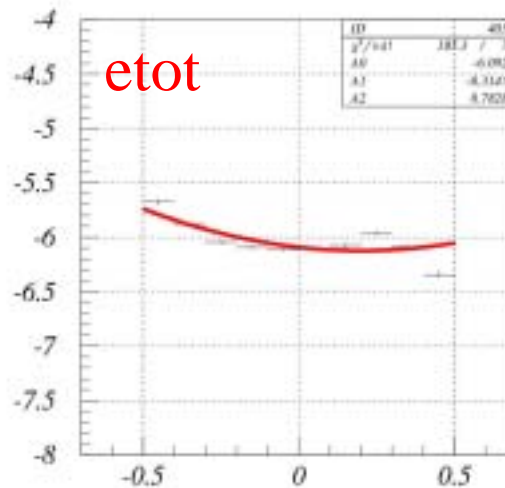


	mean	sigma	sigma/mean
1998	132.8	20.73	0.156
2002	131.5	19.89	0.151

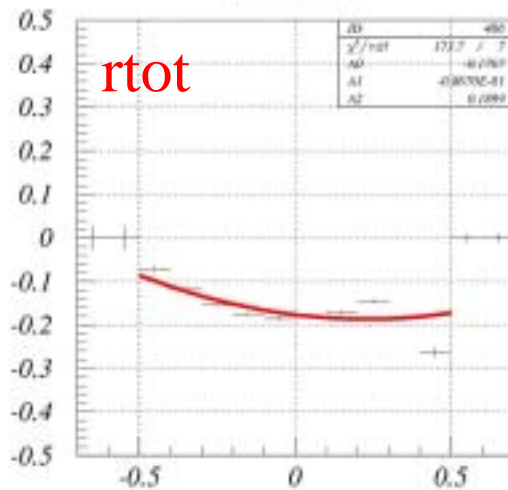
# Kinematic Correction(1)



ptot vs cos3d



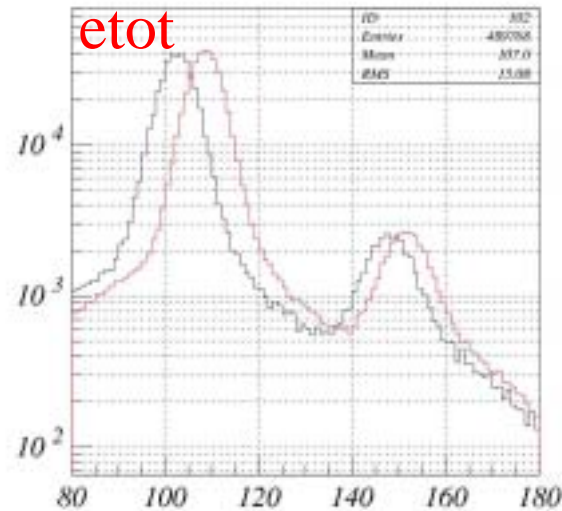
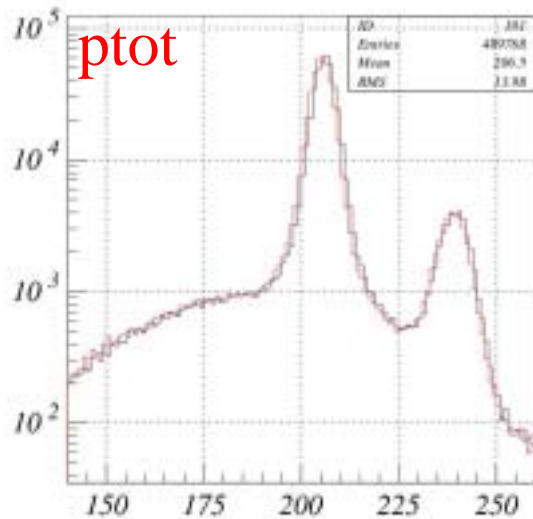
etot vs cos3d



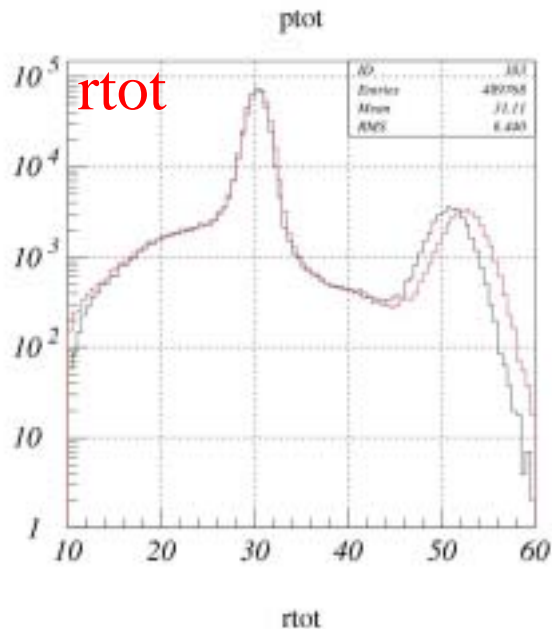
rtot vs cos3d

- $\cos 3d$  dependence
  - fit Kpi2 peak vs  $\cos 3d$  with 2<sup>nd</sup> order polynomial(smiling curve).

# Kinematic Correction(2)



Black : before  
Red : after



- Then, linear scaling was done using km2 peak.

$$x_{tot} \leftarrow a \times x_{tot} + b$$

- If the Kpi2 energy deficit was fixed, the correction should be done again.

# *Background Study*

- Around the end point, two photons from pigg will make single cluster in BV/BVL because of the narrow opening angle.

- pion background

- kp2 due to PV inefficiency
- kp2 due to 'overlapping' photon in CT

- muon background

- km3
- radiative km2

- other background

- beam related background
- accidental background

- Need to UMC study for 2 cluster events.

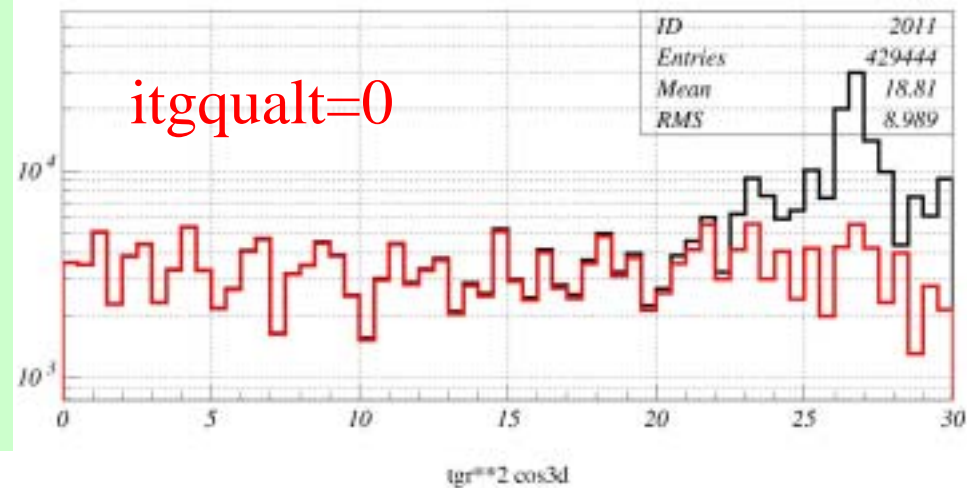


# Basic Cut

cut	events	rejection
TRBIT	548795	1.00000
TRKTIM	548374	1.00077
UTC	517420	1.05982
RANGE	511551	1.01147
TARGET	469507	1.08955
STLAY	451316	1.04031
RSHEX	448874	1.00544
LAY1617	447710	1.00260
COS3d	429444	1.04253
ITGQUALT0	217588	1.97366
TRSLIMIT	198256	1.09751

- prescaled by 20 samples were used.
- cuts used in pig analysis were tested.

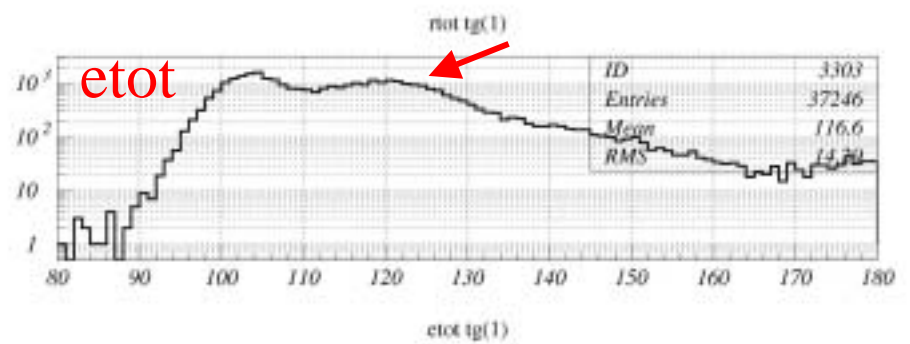
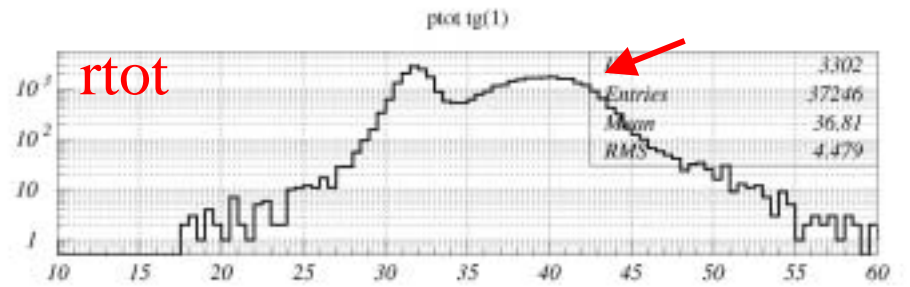
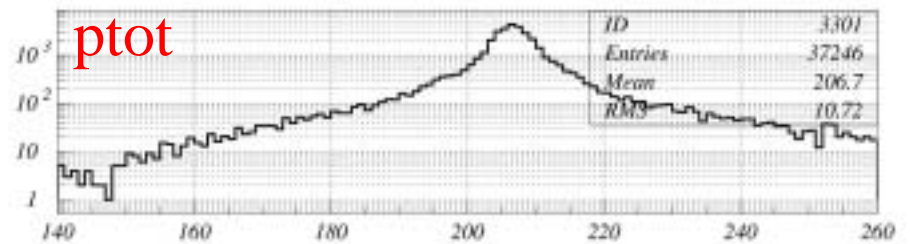
$\text{tgx}^2 + \text{tgy}^2$



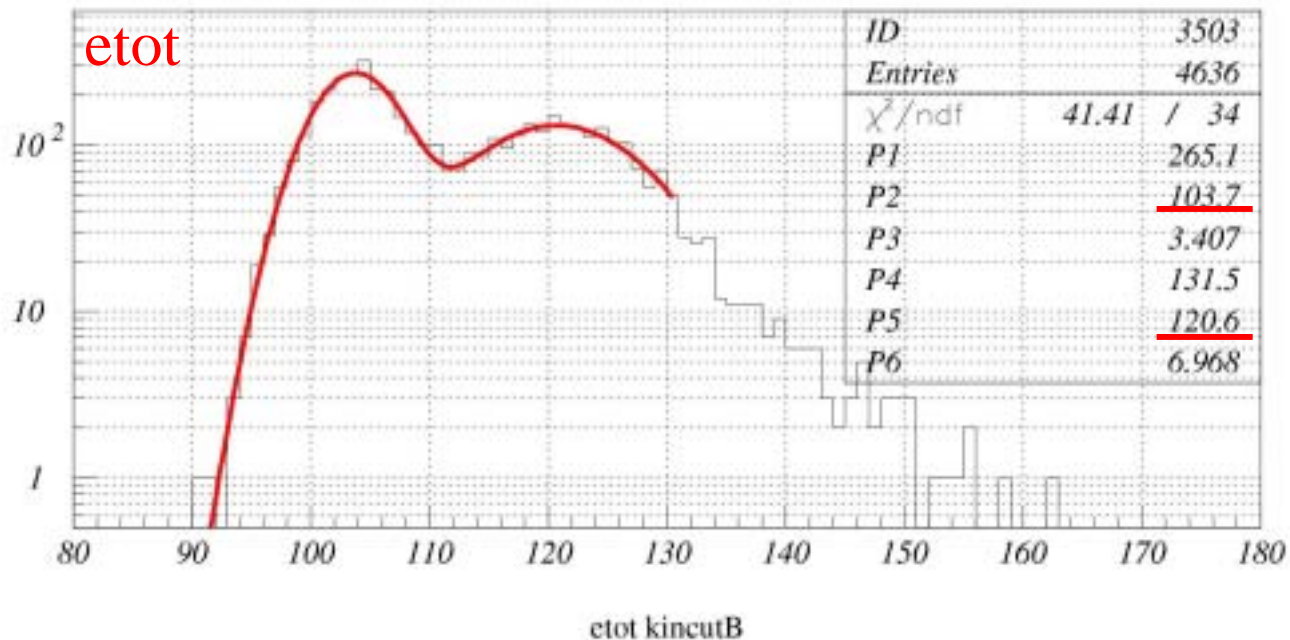
# Setup Cut(1)

cut	events	rejection
B4DEDX	175112	1.13217
B4TRS	150995	1.15972
BWTRS	136644	1.10502
DELCO	119216	1.14619
TGZ	117764	1.01233
TARGF	110275	1.06791

cut	events	rejection
EG(1)	88362	1.24799
Vgamma(3)	87645	1.00818
COSOP	37986	2.30730
TG(1)	37246	1.01987



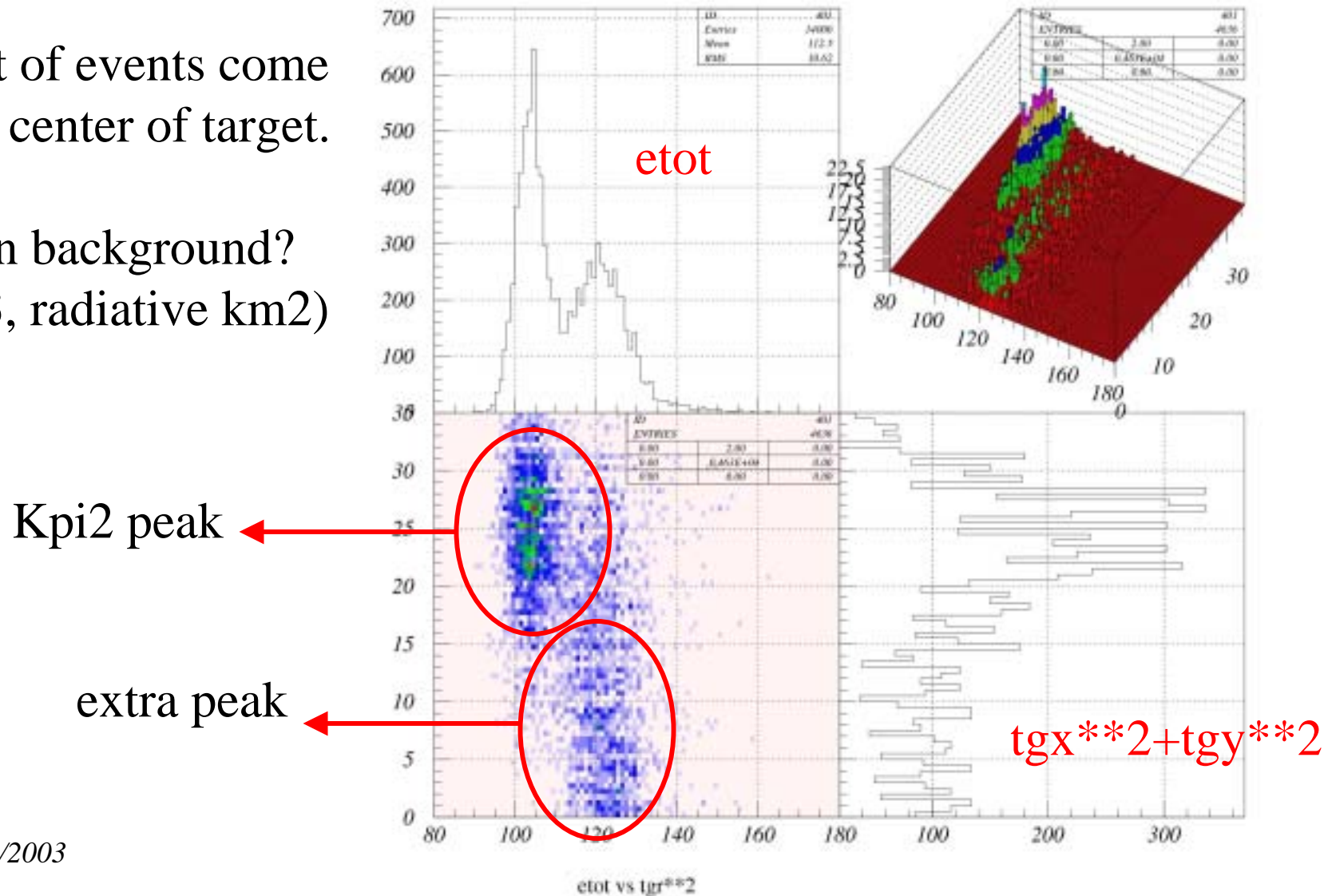
# *Extra peak(1)*



- difference between two peaks = 17 MeV  
corresponds to the minimum energy from kpi2.
- ‘overlapping’ photon in charged track?

# Extra peak(2)

- Most of events come from center of target.
- muon background? (km3, radiative km2)



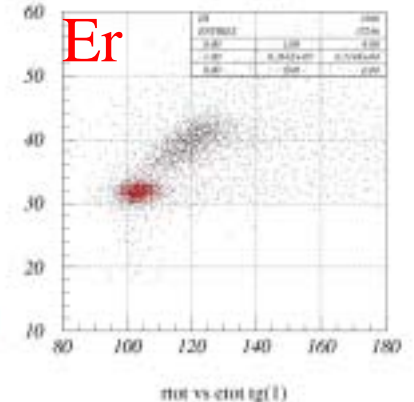
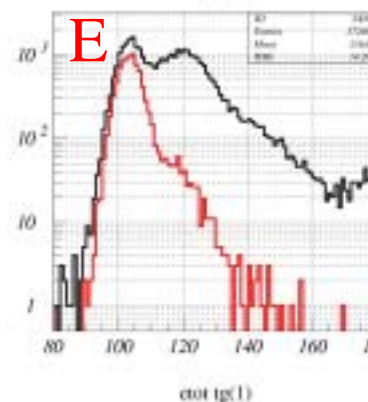
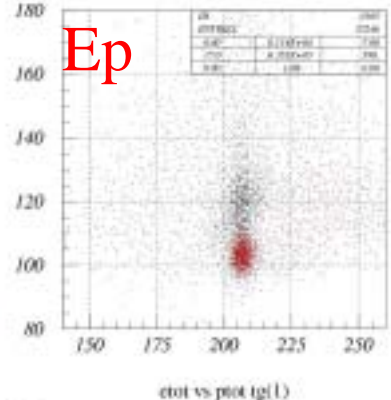
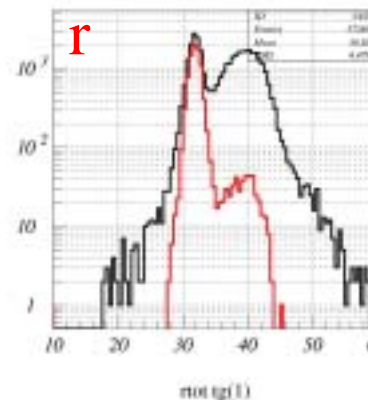
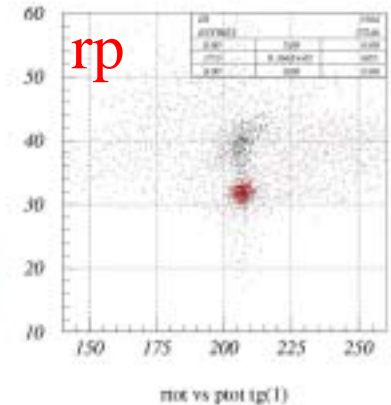
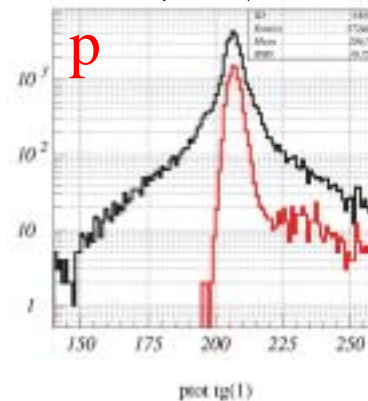
# Setup Cut(2)

- rtot and etot have extra peak other than kpi2 peak.
- muon background?  
radiative km2, km3
- ‘overlapping’ photon in CT?

cut	events	rejection
FITPI	28893	1.28910
KINCUT	18300	1.57885
RNGMOM	9451	1.93630
ELVETO	8968	1.05386

2/9/2003

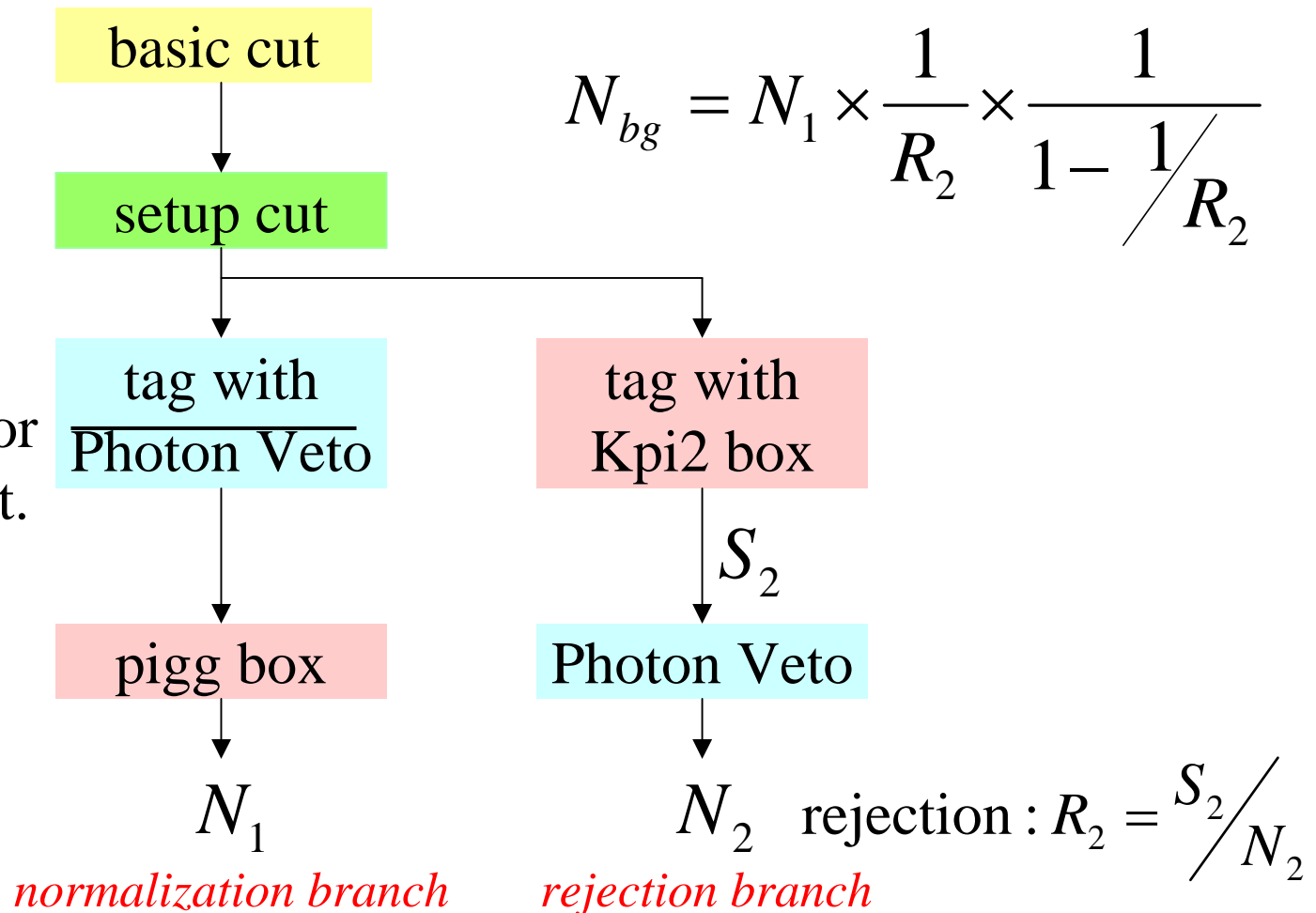
E949 analy



# *Bifurcation for Kpi2 BG due to PV ineff.*

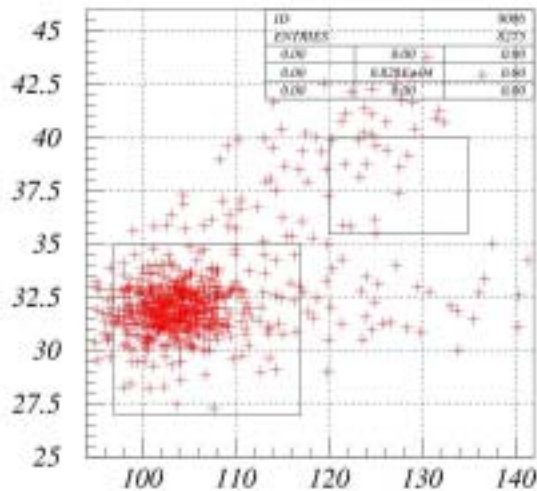
$$N_{bg} = N_1 \times \frac{1}{R_2} \times \frac{1}{1 - \frac{1}{R_2}}$$

- extra photon  
in BV/BVL or  
other PV part.

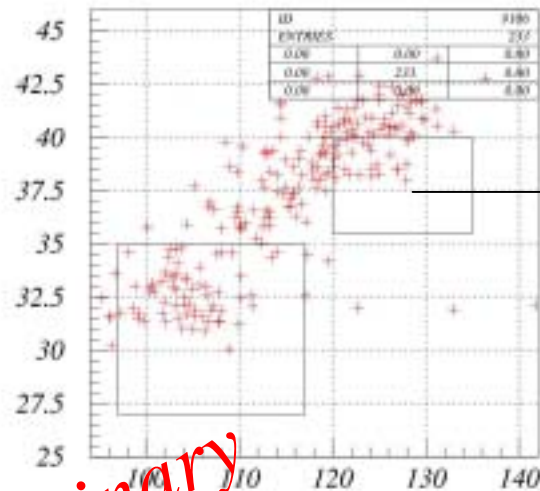




# Background estimation

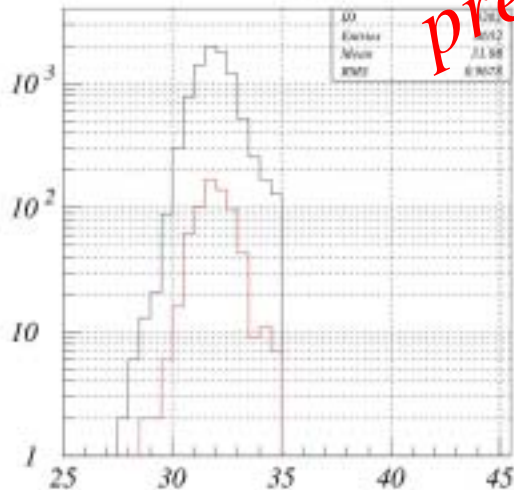


rtot vs etot pv\_bar

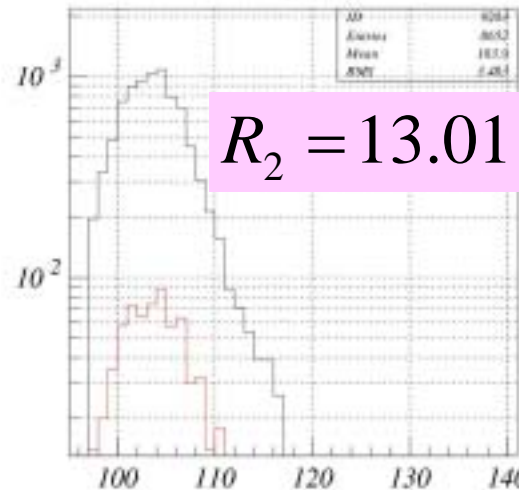


rtot vs etot pgg-p-box

26 events remained in the signal box.



rtot kp2-box



$$R_2 = 13.01$$

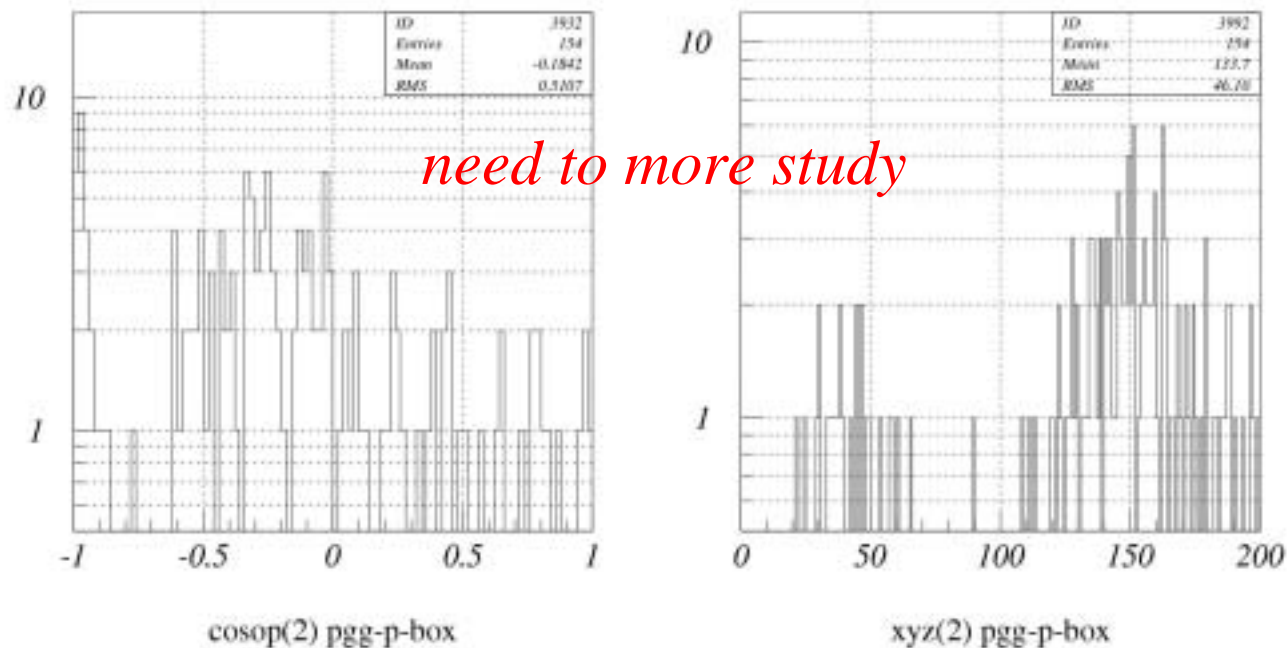
$$N_{bg} = 2.165$$

This is ps20 sample...

# Remaining events

- muon background is serious rather than Kpi2.
- Other possibility

Because of there is no requirement to 2<sup>nd</sup> cluster in Barrel  
- splitted gamma





# *Summary and Future*

- We will observe several pigg events if ChPT w/ UC is correct.
- BV/BVL calibration was done.
- Kp2 background seems to be not so serious.

## TODO

- develop cuts against apparent muon background.
- UMC study for 2 cluster events.